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Epidemiology and outcomes of non-compressible torso hemorrhage

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ABSTRACT

Background: Non-compressible torso hemorrhage (NCTH) is the leading cause of potentially preventable death in military trauma, but the civilian epidemiology is unknown. The aim of this study is to apply a military definition of NCTH, which incorporates anatomic and physiological criteria, to a civilian population treated at trauma centers in the US.
Methods: Patients (age >16 y) from 197 Level 1 trauma centers (approximately 95% of all US Level 1 centers) in the National Trauma Data Bank 2007–2009 that sustained a named torso vessel injury, pulmonary injury, grade IV solid organ injury, or pelvic fracture with ring disruption were included. Of these, patients with a systolic blood pressure <90 mmHg were considered to have NCTH. Multivariable logistic regression was used to identify patient and injury factors associated with NCTH and mortality after adjusting for the following covariates: patient (age, gender, ethnicity, and insurance status), injury (Glasgow Coma Scale, injury type, Injury Severity Score, anatomic region), and clinical (major surgical procedure, need for transfusion, and intensive care unit admission) characteristics.
Results: Of the 1.8 million patients in the 2007–2009 National Trauma Data Bank, 249,505 met the anatomic criteria for non-compressible torso injury (NCTI). Of these, 20,414 (8.2%) patients had associated hemorrhage. The rate of pulmonary and torso vessel injury was similar (53.4% and 50.6%, respectively), with solid organ injury identified in 27.0% of patients and pelvic injury in 8.9%. The overall mortality rate of patients with NCTI and NCTH was 6.8% and 44.6%, respectively. The most lethal injury was major torso vessel injury (OR 1.54, 95% CI 1.33–1.78), followed by pulmonary injury (OR 1.32, 95% CI 1.18–1.48). Lower mortality was found in patients with pelvic injury (OR 0.80, 95% CI 0.65–0.98).
Conclusions: The military definition of NCTH can be usefully applied to civilians to identify patients with lethal injuries and high resource needs. Investigating the implications of NCTH on patient triage is recommended.

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1. Introduction

Hemorrhage is the leading cause of potentially preventable death in both military and civilian trauma, accounting for over 80% of deaths in recent reports [1–4]. The wars in Afghanistan and Iraq have precipitated a reappraisal of the classification of death from hemorrhage, which can be broadly classified into compressible and non-compressible [5]. Hemorrhage involving the extremities is accessible and amenable to external compression, hence rapidly amenable to control. Mortality from extremity hemorrhage has decreased significantly with the introduction of specific measures such as hemostatic gauze and tourniquets [6–8].

However, significant hemorrhage originating within the torso is particularly challenging as there is no reliable method of control without an operating room or interventional suite. Data from the Department of Defense Trauma Registry analyzing the cause of death of US military personnel over 10 y reported that truncal hemorrhage accounted for 67.3% of potentially preventable deaths [9]. Thus, the early identification of patients with non-compressible torso hemorrhage (NCTH) may assist in prompt interventions leading to improved survival.

Despite the intuitive terminology, a unifying definition to characterize this injury pattern has been lacking. Earlier studies have focused on specific organ systems, such as pulmonary or solid abdominal organs. Military researchers have strived to develop a novel definition of this injury pattern involving the torso (Fig. 1) [10]. This definition has since been applied to military datasets characterizing the epidemiology of non-compressible torso injury (NCTI) and hemorrhage in military personnel injured in conflicts in Iraq and Afghanistan during the last decade [11,12]. However, application of this injury pattern has not been translated to civilian trauma to date.

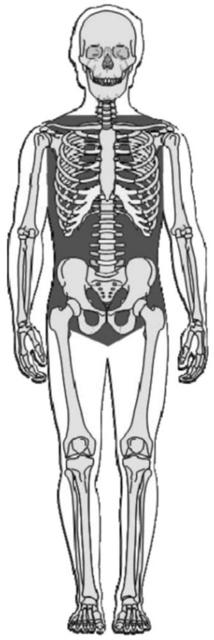

Fig. 1 – The shaded region demonstrates the location of NCTH.

NCTI and associated hemorrhage in the civilian setting has important implications. Recognition and progression of this injury pattern in civilian trauma is largely unexplored and unknown. However, in the studies exploring civilian preventable mortality, hemorrhage is the number one contributor [13,14]. Identification of patient and injury factors associated with this lethal, yet potentially survivable, injury may help to channel timely interventions to improve survival/outcomes.

The objectives of this study are to extend the use of a military definition of NCTI to a civilian population in order to (1) characterize the epidemiology of NCTI at Level 1 trauma centers in the US, (2) identify any potential role of socio-demographic and injury characteristics in predisposition to NCTH, and (3) explore associations between these characteristics and mortality in patients who develop NCTH.

2. Methods

This study is an analysis of all adult patients entered in the National Trauma Data Bank (NTDB) 2007–2009 dataset. The NTDB is a prospectively collected trauma registry maintained by the American College of Surgeons and contains data contributed by more than 900 trauma centers in the United States and its territories. This national database now encompasses data from approximately 95% of all Level 1 trauma centers. Data reporting to the NTDB is voluntary and the proportion of missing centers is >5% for Level 2 to Level 4 trauma centers. Thus, these centers were excluded to make this study representative of trauma care at Level 1 centers in the US. Patients aged ≥16 y from all Level 1 trauma centers that met the anatomic criteria defining NCTI were included (Table 1). Patients who were dead on arrival and patients with burns were excluded from this analysis.

Pursuant to previously published work, NCTI was defined as at least one of the following anatomic injuries: (1) pulmonary injury, (2) named torso vessel injury, (3) grade 4 solid organ injury (liver, kidney, spleen), and (4) open pelvic ring fracture [10]. These were classified using a combination of International Classification of Diseases 9 (ICD-9) diagnosis codes, ICD-9 procedure codes, and Abbreviated Injury Scale codes. NCTH was defined in a sub-group of patients who, in

Table 1 – Definitions of NCTI and hemorrhage.

Anatomic criteria	Physiological criteria
NCTI	NCTH
(1) Pulmonary injury (massive hemothorax, pulmonary vascular injury) (2) Solid organ injury ≥grade 4 (liver, kidney, spleen) (3) Named axial torso vessel (4) Pelvic fracture with ring disruption	Anatomic criteria, plus Systolic blood pressure <90 mmHg

addition to their anatomic injury, had a systolic blood pressure of ≤90 mmHg on arrival to the emergency department (Fig. 1). The primary outcomes of interest were (1) identification of the sub-group with NCTH and (2) in-hospital mortality in patients with NCTH.

Information on the following variables were extracted from the NTDB and categorized. Patient demographics included age (in 10 y age groups), gender (male/female), race/ethnicity (Caucasians, African Americans, Hispanics, and Others) [15], and insurance status (insured *versus* uninsured). Uninsured patients were defined only as patients who were listed as "self-pay," whereas patients with all other types of funding, including Medicaid and Medicare, were classified as insured [16]. Injury characteristics included Injury Severity Score (ISS) categorized as 0–9, 9–15, 16–24, 25–75, Glasgow Coma Scale (GCS) score categorized as 3–5, 6–9, 10–12, 13–15, type of injury (blunt *versus* penetrating), mechanism of injury (motor vehicle traffic, fall, pedestrian, cyclist, motorcyclist, stab, gunshot wound, and others) and anatomic site of injury (pulmonary, torso vessel injury, solid organ injury, and pelvic injury). Clinical characteristics that were studied included the following dichotomous variables: major surgical intervention, blood transfusion (ICD-9 diagnosis codes 99.0, 99.02–99.07), intensive care unit (ICU) admission and ventilator requirement. Major surgical procedures were identified using the following ICD-9 codes: nervous system (01.00–05.99), respiratory, cardiovascular, digestive, and urinary system (30.00–59.99), and musculoskeletal system (77.00–78.99, 81.00–81.99, 83.00–84.99).

2.1. *Statistical analysis*

Univariate analyses were done to determine the associations of the aforementioned variables with NCTH and mortality in patients with NCTH. Student's *t*-test was used to compare continuous variables. If the assumptions of this test were not met, Mann-Whitney U test was used instead. Chi-squared analysis was used to compare categorical variables. Variables which were found to be statistically significant on univariate analyses or were biologically/clinically plausible were used for multivariate analysis. Multivariate logistic regression was used to determine the independent predictors of NCTH and mortality in patients with NCTH. The final model included the following variables: age, gender, race, insurance status, GCS score, ISS, type, mechanism and site of injury, major surgical intervention, blood transfusion, and ICU admission. Clustering by facility ID was performed during multivariate analyses to control for the potential inter-facility differences in treatments and procedures [17]. All analyses were done using Stata/MP v. 11 (Stata, College Station, TX), and statistical significance was defined as a P value < 0.05.

3. Results

The NTDB 2007–2009 dataset included approximately 1.8 million patients. Of these, 15% of the patients were admitted with NCTI to a Level 1 trauma center. After excluding patients who were dead on arrival and pediatric patients, there were 259,171 patients. Only patients with blunt and penetrating injury were included, arriving at a sample size of 249,505 patients with NCTI (Fig. 2).

Of the 249,505 patients, 20,414 (8.2%) had evidence of ongoing hemorrhage and formed the NCTH subgroup. Table 2 demonstrates the sociodemographic and clinical characteristics of the study population. The majority of patients with NCTI were young, with approximately 60% of patients between the ages 16 and 45. The majority of patients were male (72.0%) and suffered a blunt injury (79.1%). The most common site of injuries was pulmonary injury (53%), followed by torso vascular injury (51%), solid organ injury (27%), and pelvic injury (9%). Major surgery was required in 68% of the patients, and 51% of the patients were admitted to an ICU. The overall mortality rate of patients with NCTI and NCTH was 6.8% and 44.6%, respectively.

Table 2 is further stratified by NCTI and NCTH to highlight significant differences amongst these groups. Patients with NCTH were more likely to be older, male, non-Caucasian, and uninsured. These patients also sustained a greater overall injury burden, proportionally more penetrating injuries as well as pulmonary, torso vascular, solid organ, and pelvic injuries. In terms of care, NCTH patients also required more blood transfusions, major surgical procedures, ICU admissions, and ventilator use more frequently. Patients with NCTH also had a significantly higher rate of mortality.

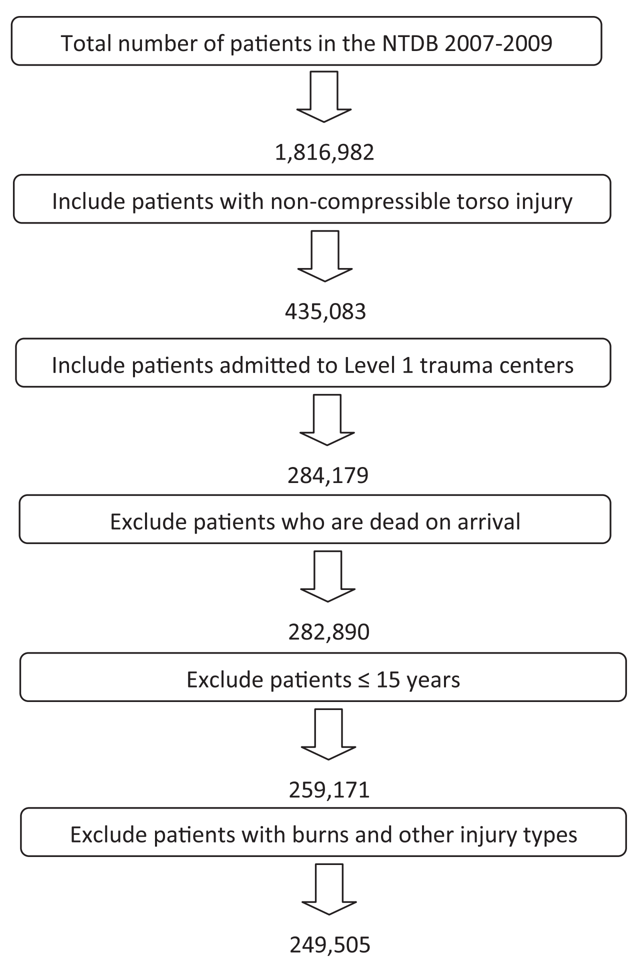

Fig. 2 – Patient selection flow-chart.

Table 2 – Epidemiologic characteristics of patients with NCTI and NCTH.

	Non-compressible torso injury (NCTI) 249,505 (100)	Non-compressible torso hemorrhage	
		Yes: 20,414 (8.2) *n* (%)	No: 221,490 (91.6) *n* (%)
Age (y)			
16–25	68,567 (27.5)	5450 (26.7)	61,009 (27.5)
26–35	43,961 (17.6)	3968 (19.4)	38,732 (17.5)
36–45	38,085 (15.3)	3140 (15.4)	33,868 (15.3)
46–55	37,776 (15.1)	3183 (15.6)	33,478 (15.1)
56–65	24,232 (9.7)	1987 (9.7)	21,489 (9.7)
66–75	15,008 (6.0)	1165 (5.7)	13,306 (6.0)
≥76	20,223 (8.1)	1442 (7.1)	18,110 (8.2)
Missing	1653 (0.7)	79 (0.4)	1498 (0.7)
Gender			
Male	179,646 (72.0)	15,101 (74.0)	159,082 (71.8)
Female	67,091 (26.9)	4977 (24.4)	60,058 (27.1)
Missing	2768 (1.1)	336 (1.7)	2350 (1.1)
Race			
Caucasian	150,048 (60.1)	10,605 (52.0)	135,196 (61.0)
African-American	46,371 (18.6)	5307 (26.0)	39,778 (18.0)
Hispanic	5004 (2.01)	460 (2.3)	4461 (2.0)
Others	32,112 (12.9)	2750 (13.5)	28,549 (12.9)
Missing	15,970 (6.4)	1292 (6.3)	13,506 (6.1)
Insurance status			
Insured	152,920 (61.3)	10,882 (53.3)	138,193 (62.4)
Uninsured	45,290 (18.2)	5385 (26.4)	38,948 (17.6)
Missing	51,295 (20.6)	4147 (20.3)	44,349 (20.0)
GCS total			
3–5	38,756 (15.5)	10,165 (49.8)	27,405 (12.4)
6–9	6418 (2.6)	598 (2.9)	5687 (2.6)
10–12	5705 (2.3)	608 (3.0)	4982 (2.3)
13–15	187,005 (75.0)	8551 (41.9)	176,802 (79.8)
Missing	11,621 (4.7)	492 (2.4)	6614 (3.0)
ISS			
0–9	33,710 (13.5)	1399 (6.9)	31,348 (14.2)
9–15	76,333 (30.6)	3422 (16.8)	71,054 (32.1)
16–24	63,693 (25.5)	4167 (20.4)	58,025 (26.2)
25–75	65,855 (26.4)	10,648 (52.2)	53,077 (24.0)
Missing	9914 (4.0)	778 (3.8)	7986 (3.6)
Mechanism			
Motor vehicle collision	83.270 (33.4)	6195 (30.4)	74,967 (33.9)
Fall	45,164 (18.1)	1865 (9.1)	41,816 (18.9)
Pedestrians struck	11,307 (4.5)	1516 (7.4)	9462 (4.3)
Cyclist	2003 (0.8)	170 (0.8)	1800 (0.8)
Motorcyclist	21,588 (8.7)	1761 (8.6)	19,235 (8.7)
Stab	24,436 (9.8)	2079 (10.2)	21,631 (9.8)
Gunshot wound	27,615 (11.1)	5124 (25.1)	21,261 (9.6)
Others	34,122 (13.7)	1704 (8.4)	31,318 (14.1)
Injury			
Blunt	197,454 (79.1)	13,211 (64.7)	178,598 (80.6)
Penetrating	52,051 (20.8)	7203 (35.3)	42,892 (19.4)
Anatomic focus			
Pulmonary injury	133,214 (53.4)	13,909 (68.1)	115,224 (52.0)
Torso vessel injury	126,242 (50.6)	13,846 (67.8)	108,122 (48.8)
Solid organ injury	67,356 (27.0)	7310 (35.8)	57,895 (26.1)
Pelvic injury	22,210 (8.9)	1887 (9.2)	19,779 (8.9)
Clinical care			
Blood transfusion	27,577 (11.0)	3904 (19.1)	22,496 (10.2)
Major surgical procedure	169,816 (68.1)	16,245 (79.6)	148,075 (66.9)
ICU admission	127,732 (51.2)	11,592 (56.8)	112,914 (51.0)
Need for ventilator	67,361 (27.0)	9329 (45.7)	56,070 (25.3)
Death	25,813 (10.4)	9105 (44.6)	15,142 (6.8)

Table 3 demonstrates the factors associated with the development of NCTH in patients with NCTI. After adjusting for demographic, injury, and clinical characteristics, we found that older age, African-American race, lower GCS score, higher ISS, penetrating injury, pulmonary injury, torso vascular injury, solid organ injury, pelvic injury, and need for

Table 3 – Adjusted OR for predictors of NCTH.

	OR (95% CI)
Age (y)†	
26–35	1.21 (1.15–1.28)*
36–45	1.31 (1.24–1.38)*
46–55	1.62 (1.52–1.73)*
56–65	1.81 (1.68–1.96)*
66–75	2.08 (1.88–2.30)*
≥76	2.06 (1.85–2.28)*
Male gender	0.88 (0.84–0.93)*
Race‡	
African-American	1.34 (1.23–1.45)*
Hispanic	1.17 (0.99–1.20)
Others	1.09 (0.99–1.20)
Insured	0.76 (0.69–0.82)*
Total GCS score§	
6–9	0.33 (0.28–0.38)*
10–12	0.38 (0.33–0.43)*
13–15	0.18 (0.16–0.20)*
ISS‖	
9–15	1.27 (1.14–1.42)*
16–24	1.78 (1.56–2.03)*
25–75	2.61 (2.22–3.06)*
Penetrating injury	2.72 (2.46–3.01)*
Pulmonary injury	1.66 (1.55–1.77)*
Torso vessel injury	1.75 (1.56–1.97)*
Solid organ injury	1.62 (1.54–1.72)*
Pelvic injury	1.38 (1.19–1.62)*
Transfusion	1.40 (1.22–1.60)*
Major surgery	1.12 (0.99–1.28)
ICU admission	0.58 (0.52–0.64)*

* Significant at $P < 0.05$.
† Reference group for age = 16–25 y.
‡ Reference for race = Caucasians.
§ Reference for total GCS score = 3–5.
‖ Reference group for ISS = 0–9.

transfusion were associated with an increased odds of developing NCTH.

Table 4 explores associations of mortality in patients with NCTH, with a summary of values for both NCTI and NCTH found in Supplementary Table 1. After adjusting for demographic, injury and clinical factors, we found that older age, African-American race, increasing ISS, penetrating injury, pulmonary injury and torso vascular injury increased the odds of mortality. In contrast, pelvic injury, major surgical procedure, ICU admission, and insurance coverage decreased the odds of mortality (Table 5).

4. Discussion

This is the first civilian study to use a novel military definition of NCTH to characterize the epidemiology and outcomes of this important constellation of injuries. Approximately 15% of patients admitted to Level 1 trauma centers in the US from 2007–2009 in the National Trauma Data Bank had NCTI. Of these, 8.2% demonstrated active hemorrhage. NCTH was associated with an extremely high mortality rate of 45%, with torso vessel and pulmonary injury identified as independent predictors of death. Several important sociodemographic and injury characteristics predisposing to NCTH and mortality in patients with NCTI were also identified.

The importance of uncontrolled torso hemorrhage has been re-emphasized by US military studies analyzing data from the wars in Iraq and Afghanistan. Holcomb *et al.* reviewed the autopsy findings of personnel killed in the early years of these conflicts and used an expert peer-review panel to classify fatalities as nonsurvivable or potentially survivable [2]. Torso hemorrhage was found to be the leading cause of potentially survivable death. A further analysis of US military deaths from 2003–2004 and 2006 showed that hemorrhage accounted for 87% and 83% of all deaths, respectively, in these cohorts of patients [18]. Among patients with hemorrhage, 50% were due to NCTH and 33% were due to extremity injury. Eastridge *et al.* has performed the most comprehensive cause of death analysis to date, demonstrating that 90% of potentially survivable deaths are hemorrhage-related, of which the trunk is the primary focus in majority of the cases (67%) [9].

In this context, military researchers strived to establish a unifying definition of this injury pattern. An initial definition of NCTI and hemorrhage was described by researchers at the US Army's Institute of Surgical Research and is based on previously reported anatomic and physiologic criteria [10]. In order to be comprehensive, the anatomic criteria (i.e., the *injury*) included named torso vessel, pulmonary, solid organ and pelvic disruption, all identified foci of major hemorrhage. Furthermore, in order to identify patients in shock (i.e., *active hemorrhage*), an admission systolic blood pressure <90 mmHg added a physiological criterion.

Following the application of this definition, findings from the U.S. Dept of Defense Trauma Registry (DoDTR) identified an incidence of NCTI of 12.7%, of which 17.1% had evidence of ongoing hemorrhage [11]. Major arterial and pulmonary injuries were identified as the most mortal injury complexes. Findings are similar from the UK Joint Theatre Trauma Registry, which included an analysis of patients who died prior to hospital admission [12]. The overall case fatality rate was 85.5%, with only 25% of patients actually surviving to hospital admission. This fatality rate is almost four times higher than that associated with other battle-related injury. Again, major arterial and pulmonary injuries were identified as most lethal.

Recognition and progression of this injury pattern in civilian trauma is largely unexplored and unknown. Military trauma is significantly different to civilian as it largely involves explosive mechanisms producing higher energy, penetrating wounds, whereas civilian trauma is predominantly blunt in nature. Despite these differences, it is important to recognize that hemorrhage remains the leading cause of potentially preventable deaths in civilian setting also, accounting for 30%–40% of overall deaths [13,14]. The current study demonstrates the high mortality burden of NCTH, highlighting the clinical importance of identifying these patients, as early interventions and triage are critical to their survival. Identification of patient and injury factors associated with NCTH will aid in appropriate triaging, aggressive resuscitation, and surgery to improve survival.

This study explores the temporal relationship between NCTI, NCTH, and death. Approximately 15% of patients admitted to Level 1 trauma centers fulfill the criteria for NCTI.

Table 4 – Univariate analysis: associations of mortality in patients with NCTH.

	Alive $n = 10{,}901$ (53.4%)	Dead $n = 9105$ (44.6%)	*P value
	n (%)	n (%)	
Age			
16–25	2761 (51.7)	2572 (48.2)	<0.001
26–35	2104 (54.2)	1773 (45.7)	
36–45	1780 (58.1)	1286 (41.9)	
46–55	1892 (60.4)	1242 (39.6)	
56–65	1121 (57.1)	842 (42.9)	
66–75	649 (56.5)	499 (43.5)	
≥76	572 (40.6)	836 (59.4)	
Gender			
Male	8003 (53.6)	6927 (46.4)	<0.001
Female	2868 (58.2)	2064 (42.0)	
Race			
Caucasian	6227 (59.2)	4299 (40.9)	<0.001
African-American	2466 (47.2)	2759 (52.8)	
Hispanics	257 (56.4)	199 (43.5)	
Others	1462 (53.3)	1279 (46.7)	
Insurance status			
Insured	6752 (62.3)	4079 (37.7)	<0.001
Uninsured	2023 (38.2)	3270 (61.8)	
GCS total			
3–5	2406 (24.3)	7506 (75.7)	<0.001
6–9	384 (65.0)	207 (35.0)	
10–12	439 (73.4)	159 (26.6)	
13–15	7374 (87.6)	1047 (12.4)	
ISS			
0–9	895 (65.0)	482 (35.0)	<0.001
9–15	2515 (74.7)	853 (25.3)	
16–24	2685 (65.7)	1404 (34.3)	
25–75	4381 (42.1)	6026 (57.9)	
Mechanism			
Motor vehicle collision	3461 (56.8)	2632 (43.2)	<0.001
Fall	1226 (66.6)	615 (33.4)	
Pedestrians struck	737 (46.3)	854 (53.7)	
Cyclist	141 (56.6)	108 (43.4)	
Motorcyclist	964 (55.6)	769 (44.4)	
Stab	1513 (73.9)	534 (26.1)	
Gunshot wound	1914 (38.7)	3035 (61.3)	
Others	945 (62.9)	558 (37.1)	
Injury			
Blunt	7474 (57.5)	5536 (42.6)	<0.001
Penetrating	3427 (50.0)	3569 (51.0)	
Anatomic focus			
Pulmonary injury	6319 (46.5)	7285 (53.6)	<0.001
Torso vessel injury	7706 (56.8)	5855 (43.2)	<0.001
Solid organ injury	3964 (55.4)	3188 (44.6)	<0.001
Pelvic injury	1172 (62.9)	690 (37.1)	<0.001
Clinical care			
Blood transfusion	2258 (59.3)	1550 (40.7)	<0.001
Major surgical procedure	9213 (57.9)	6691 (42.1)	<0.001
ICU admission	8489 (74.3)	2941 (25.7)	<0.001
Need for ventilator	5386 (58.5)	3814 (41.5)	<0.001

*Significant at $P < 0.05$.

Of these, approximately 8% progress to NCTH. Mortality rates are significantly different in patients with and without associated hemorrhage (45% *versus* 7%). Older age, African-American race, lower GCS score, higher ISS, penetrating injury, pulmonary injury, torso vascular injury, solid organ injury, pelvic injury, and need for transfusion were associated with NCTH. Similarly, older age, African-American race, increasing ISS, penetrating injury, and pulmonary injury and torso vascular injury increased the odds of mortality in patients with NCTH. Many of these factors have been previously described to be associated with mortality in the general trauma population.

African-American and uninsured patients were more likely to develop NCTH and die after developing this injury pattern in this analysis. Ethnic and insurance disparities have not been explored in this context yet. Although underlying

Table 5 – Adjusted OR for covariates associated with death on multivariate analyses in patients with NCTH.

	Mortality (n = 14,634)
	OR (95% CI)
Age†	
26–35	0.91 (0.79–1.05)
36–45	1.05 (0.90–1.22)
46–55	1.25 (1.10–1.43)*
56–65	2.26 (1.83–2.80)*
66–75	2.98 (2.27–3.92)*
≥76	12.56 (9.56–16.50)*
Male gender	1.03 (0.90–1.18)
Race‡	
African-American	1.49 (1.26–1.75)*
Hispanic	1.05 (0.74–1.50)
Others	1.11 (0.90–1.37)
Insured	0.48 (0.41–0.57)*
Total GCS score§	
6–9	0.22 (0.17–0.29)*
10–12	0.14 (0.11–0.19)*
13–15	0.05 (0.04–0.06)*
ISS‖	
9–15	0.96 (0.77–1.20)
16–24	2.16 (1.69–2.76)*
25–75	4.58 (3.42–6.13)*
Penetrating injury	1.30 (1.14–1.48)*
Pulmonary injury	1.32 (1.18–1.48)*
Torso vessel injury	1.54 (1.33–1.78)*
Solid organ injury	1.03 (0.90–1.17)
Pelvic injury	0.80 (0.65–0.98)*
Transfusion	1.16 (0.96–1.41)
Major surgery	0.75 (0.60–0.94)*
ICU admission	0.08 (0.06–0.10)*

* Significant at $P < 0.05$.
† Reference group for age = 16–25 y.
‡ Reference for race = Caucasians.
§ Reference for total GCS score = 3–5.
‖ Reference group for ISS = 0–9.

reasons for the association of ethnicity and insurance status with NCTI and mortality cannot be explained from this study, future research in this area is warranted. In the NCTH subgroup, patients with pelvic injury were less likely to die. A recent study characterizing the epidemiology of pelvic ring fractures has reported that 23% of trauma patients with pelvic fractures suffer from pre-hospital death [19]. Secondly, further analyses showed that in patients with pelvic injury, approximately 86% had an injury to one of the three other anatomic regions in this study. Thus, this finding may be due to a combination of factors including survival bias and its relation to other anatomic domains. Spectrum of NCTI, NCTH, and death may be comparable to spectrum of systemic inflammatory response system, sepsis, and septic shock, with mortality increasing at each step. Thus, recognition of this injury pattern at an early stage will assist in reducing mortality.

The NTDB consists of data contributed voluntarily from trauma centers and has inherent limitations, including selection bias, missing or invalid responses, and variable data collection. We reduced the potential impact of these limitations by (1) limiting our analysis to the 2007 to 2009 datasets that were collected after the implementation of the National Trauma Data Standard, which has played a significant role in improving the reliability of the data, and (2) by including patients from Level 1 trauma centers. The NTDB now includes data from 95% of all Level 1 trauma centers in the US, and findings of this study may be generalizable to trauma care at Level 1 centers throughout the country.

5. Conclusion

Despite the important differences between military and civilian trauma, we have demonstrated the utility of applying a military definition of NCTH to a civilian trauma registry. Civilian NCTH is highly lethal, with vascular and pulmonary injury as the most mortal injury complexes. These findings are consistent with the military literature, emphasizing the need for better identification of these patients. The use of a consistent definition of NCTH will permit the comparison of registry outcomes and the efficacy of future novel resuscitative strategies.

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Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jss.2013.05.099.

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